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(54) Temperature control system for semiconductor processing facilities

(57) The present invention generally provides a system for controlling the temperature of multiple components of a semiconductor processing device or fabrication facility. The system includes a common source (18) of a heated or chilled fluid that is distributed to multiple process components (16) for use in heating or cooling. The multiple process components may be part of the same chamber or process, serve different processes in the same or different cluster tool, serve a combination of stand-alone and cluster tools, or any combination of process components (14) located in a common fabrication facility. Each process component includes a flow control valve (32,34) that controls the temperature of each component (14).

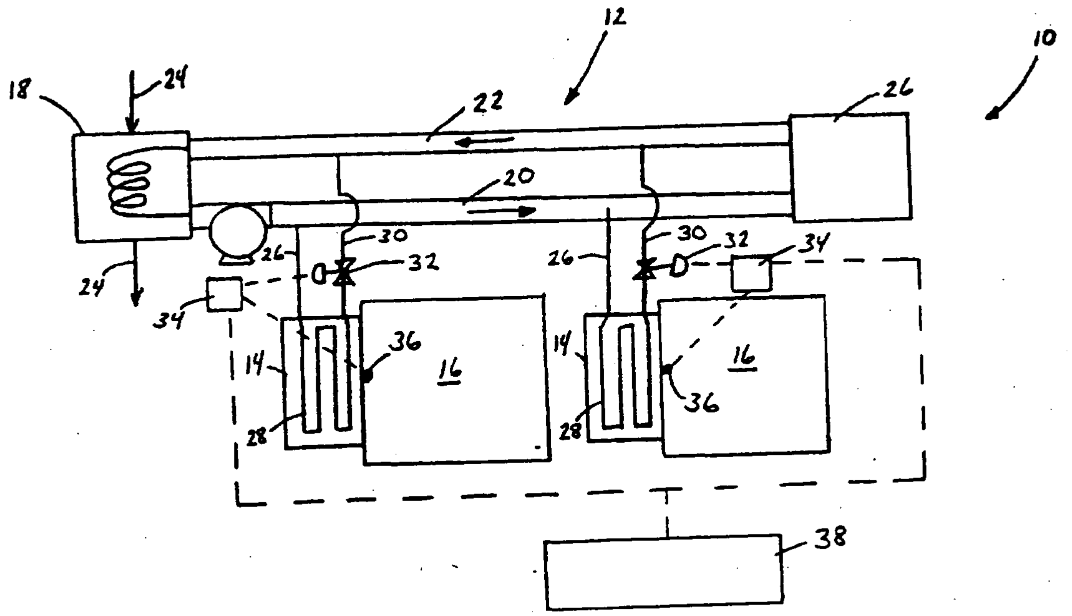

FIG. 1

EP 0 871 206 A2

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Description

The present invention relates to temperature control systems for semiconductor processing equipment. More particularly, the invention relates to heat transfer fluid systems for use in temperature control of various semiconductor processing chambers.

The manufacture of semiconductors can involve a variety of unit processes including physical vapor deposition, metal and dielectric chemical vapor deposition, plasma etching, chemical-mechanical polishing and the like. Any or all of these units may be located in a single fabrication facility. These fabrication facilities include clean room facilities in which the various unit processes are located in order to reduce particulate contamination that can cause defects in the wafer. Because it is expensive to build and operate clean rooms, only those portions of the process that are associated directly with the wafer are housed in the clean room. Presently, fabrication facilities have different levels of clean room environments so that the most sensitive processes or procedures can be carried out in the most clean environments and the most insensitive processes or procedures can be carried out in less clean environments. In this manner, the use of the most expensive space is minimized.

Furthermore, it is generally desirable to minimize the use of materials and equipment in the clean room that can generate particles and release them into the air. Therefore, materials that out gas contaminants or generate particles are kept outside of the clean room area that houses sensitive processes. Likewise, equipment that emits byproduct gases, generates particles, alters the humidity or suffers occasional spills are kept in remote locations outside of clean room areas.

While each process has distinctive characteristics and may require specific accommodations for installation and operation, there are some aspects of their operation that are similar. For example, many semiconductor processes are carried out under specific conditions, such as temperature and pressure. These temperatures and pressures may vary between processes and may even vary within the same process over time or according to the particular process recipes being performed.

Temperature control of processing conditions may be used beneficially for many purposes. For example, temperature control of the substrate receiving surface of a support member can enhance uniformity and deposition rate on the substrate. Temperature control of the processing apparatus side walls can also enhance such processing by reducing undesirable condensation of chemical vapors on the chamber walls. Cooling of wafers following certain warm deposition processes speeds the solidification of the deposited materials prior to additional processing and reduces out gassing of undesirable and often corrosive gases when the wafer is removed from the cluster tool.

In those applications, such as temperature control of chamber walls, where a heat transfer fluid may be used to heat or cool a processing unit or chamber component, the fluid is circulated through a heat exchanger which is controlled to deliver the fluid at the temperature desired of the chamber component. For example, if a given substrate is to be processed in a manner that calls for a chamber wall temperature of 150°C, the heat exchanger provides sufficient heat to the circulating fluid so that the fluid temperature leaving the heat exchanger is about 150°C. The setpoint temperature of the exchanger output may be increased to account for an average temperature drop through the tubing and chamber wall. However, this type of adjustment does not allow the temperature of the chamber wall to be maintained under changing thermal loads associated with substrate processing. Separate, dedicated heat exchangers have been required to provide for independent fluid temperatures at different processing units.

A strong need exists for a system that can control the temperature of semiconductor processing chambers despite changes in the thermal loads associated with substrate processing. There is also a need for a temperature control system that involves fewer parts and can rapidly and effectively change the surface temperature of a process element. The system should possess the ability to reduce thermal losses and thermal lag. It would also be desirable if the system provided independent control for each process component.

The present invention provides a semiconductor fabrication system that comprises a heat exchanger, a manifold in fluid communication with the heat exchanger, a plurality of fluid passages in parallel fluid communication with the manifold wherein each fluid passage has a flow control valve, and a plurality of process components in thermal communication with one of the fluid passages. The manifold may comprise a pump, supply line, return line and a pressure control member in fluid communication between the supply line and the return line. Each flow control valve may include a temperature controller to control the temperature of the process component. It is preferred that the system include a central process controller in electronic communication with the temperature controllers to provide a setpoint to each temperature controller.

The invention also provides a semiconductor fabrication system that comprises a first source of a heat transfer fluid, a plurality of fluid passages in parallel fluid communication with the first source wherein each fluid passage has a flow control valve, and a plurality of process components in thermal communication with one of the fluid passages. The heat transfer fluid may be supplied at either a temperature that is less than the lowest temperature required by the process components or a temperature that is greater than the highest temperature required by any of the process components and has the capacity to support multiple process chamber elements. Optionally, the system may further comprise a second source of a heat transfer fluid, a plurality of fluid passages in parallel fluid communication with the second source wherein each fluid passage has a flow control valve, and a plurality of process components in thermal communication with one of the fluid passages. The first and second sources may be in fluid communication with the same or different plurality of fluid passages. In some applications it will be desirable to have the second source of a heat transfer fluid supplied at lower temperature than the first source.

The invention also provides a method of controlling the temperature of multiple processing components. The method comprises providing a heat transfer fluid to a manifold and controlling the flow of the heat transfer fluid to the individual processing components. It may be desirable to maintain a continuous flow of the heat transfer fluid through the manifold. The continuous flow may be accomplished by controlling the pressure in the manifold.

So that the manner in which the above recited features and advantages of the present invention are attained can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereofwhich are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

Figure 1 is a schematic diagram of a temperature control system using a manifold for distribution of a heat transfer fluid to the components of multiple processes.

Figure 2 is a schematic diagram of a temperature control system using a manifold for distribution of a heat transfer fluid to multiple process components of a single process.

Figure 3 is a schematic diagram of a temperature control system using two manifolds for distribution of heat transfer fluids at different temperatures to multiple components of multiple processes.

The present invention generally provides a system for controlling the temperature of multiple components or devices of semiconductor processing equipment. The system includes a source of a heated or chilled fluid that is distributed to multiple process components for use in heating or cooling of those components. The multiple process components may be part of the same chamber or process unit, serve different process units in the same or different cluster tool, serve a combination of stand-alone process units and cluster tools, or any combination of process components located in a common fabrication facility. Each process component includes a flow control valve that controls the temperature of each component.

In one aspect of the invention, a source of a heat transfer fluid is heated or chilled by a heat exchanger and distributed to individual process components through a header or manifold. It is preferred that the heat transfer fluid be continuously circulated through a supply line and a return line of the manifold in order to maintain the fluid at a substantially constant temperature throughout the supply line. It is also preferred that the manifold include a pressure control member, such as a flow control valve to maintain a higher pressure in the supply line than that of the return line to facilitate flow through each process component. Each process component draws fluid from the supply line and includes a control valve to adjust the flow of fluid back to the return line. The control valve may be operated to maintain a setpoint temperature in the process component itself or some other component, typically in contact with the process component. A thermocouple or other temperature sensing device provides an electronic signal that is compared with a setpoint temperature to determine the flow through the valve.

In another aspect of the invention, each individual process component may have a separate, local temperature controller that operates the control valve. Typically, the local temperature controllers will also be in electronic communication with a process controller or computer that will provide a setpoint to each of the local temperature controllers as necessary to accomplish various process recipes.

In yet another aspect of the invention, multiple sources of heat transfer fluid may be provided at different temperatures to serve different process components. For example, a first source of hot fluid may be used to heat certain components, while a second source of chilled fluid may be used to cool other components. Alternatively, first and second sources of hot or chilled fluid may be provided at different temperatures to heat or cool different components having substantially different setpoint temperatures.

Although the present invention would be beneficial to virtually every semiconductor process, the need for more consistent and accurate temperature control becomes ever more important as wafer size increases and circuit density increases. Improved temperature control plays an important role in improving process uniformity and consistency as well as reducing device defects.

Figure 1 is a schematic diagram of a temperature control system 10 using a manifold 12 for distribution of a heat transfer fluid to process components 14 of multiple processes 16. The manifold 12 is generally comprised of a heat transfer fluid source 18, a fluid supply line 20 and a fluid return line 22. The diagram shows a preferred implementation in which the fluid source 18 is a heat exchanger or chiller of any desirable type, such as a shell-and-tube, double-pipe and the like, that exchanges heat with another fluid supply 24. The preferred implementation also includes a pressure control device 27 which allows a continuous flow of fluid through the manifold 12 from the supply line 20 to the return line 22 while maintaining a pressure differential between the two lines 20 and 22. Having a higher pressure in the supply line 20 than in the return line 22 provides the motive forces necessary to push the fluid through the process component 14.

The process components 14 are in parallel, fluid communication with the manifold 12. Each process component 14 includes an inlet line 26, a fluid passage 28 through the component 14, an outlet line 30 and a control valve 32. The process component 14 can be any part of a semiconductor processing device or utility that benefits from heating or cooling, including, but not limited to, the support member or pedestal, process chamber walls, remote plasma sources and cooldown chambers. It should also be recognized that the process 16 can be any type of semiconductor process that benefits from heating or cooling, including, but not limited to, physical vapor deposition, metal and dielectric chemical vapor deposition, chemical-mechanical polishing, plasma etching and the like.

The flow control valves 32 are preferably operated by local temperature controllers 34. The controllers 34 monitor the electronic signals coming from temperature sensors 36 that are disposed in thermal communication with the associated process components 14. The temperature indicated by each temperature sensor 36 is compared with a setpoint temperature that is provided as an electronic signal to the temperature controller 34 by a process controller or computer 38. When the actual temperature measured by the sensor 36 is different than the setpoint temperature, then an electronic signal is sent to increase or decrease the opening through the control valve 32. For example, assume that the heat exchanger 18 provides a heated fluid to the supply line 20 at a rough temperature greater than the setpoint temperatures for either process component 14 at point 36. If the component temperature is below the setpoint, the valve 32 is further opened to increase the flow of heated fluid therethrough. When the component temperature is above the setpoint, the valve 32 is closed slightly to decrease the flow of heated fluid therethrough. The temperature controller can be tuned in accordance with proportional-integral-derivative (PID) or other types of control logic to provide steady control of the temperature and allow for changes in the setpoint temperature.

By providing a continuous recycle of fluid through the manifold, the heated or chilled fluid is immediately available to any process component at the rough temperature. The transportation lag experienced using dedicated heat exchangers is eliminated and each process component can be inexpensively controlled using a simple local temperature controller.

Figure 2 is a schematic diagram of a temperature control system 40 using a manifold 12 for distribution of a heat transfer fluid to multiple process components 14 of a single process unit 16. The system 40 functions in the same manner as that described in relation to Figure 1, but provides individual component temperature control even within a single process unit. Therefore, it is possible to simultaneously heat and cool separate components or heat (chill) separate components to different setpoint temperatures.

Figure 3 is a schematic diagram of a temperature control system 50 using two manifolds 12 and 52 for distribution of heat transfer fluids at different temperatures to multiple components of multiple process units. In particular, a second manifold 52 operates in a similar fashion as the manifold 12, except that the fluid is supplied at a different temperature, and includes a fluid source or heat exchanger 54, a supply line 56, a return line 58 and a pressure control device 60. The second manifold 52 is shown in fluid communication with the process components 62 via fluid inlet lines 64 and fluid outlet lines 66. The control valves 68 are preferably positioned in the outlet lines 66 and controlled by local temperature controllers 70. Note that both temperature controllers 34 and 70 may receive their setpoints from the same process controller 38.

It is also possible, as shown with component 72, to provide the option of using the fluid of either manifold 12 or 52. This may be accomplished in numerous ways, but is shown here as including a three-way valve 74 attached to the inlet and outlet lines 26 and 30. The valves 74 are also controlled by the process controller 38.

While the foregoing is directed to the preferred embodiment of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof. The scope of the invention is determined by the claims which follow.

Claims

1. A semiconductor fabrication system, comprising:

   a heat exchanger;
   a manifold in fluid communication with the heat exchanger;
   a plurality of fluid passages in parallel, fluid communication with the manifold, each fluid passage having a flow control valve; and
   a plurality of process components, each process component in thermal communication with one of the fluid passages.

2. The system of claim 1, wherein the manifold comprises a supply line and a return line.

3. The system of claim 2, further comprising a pressure control member in fluid communication between the supply line and the return line.

4. The system of any of claims 1 to 3, further comprising a pump in fluid communication with the manifold.

5. The system of any of claims 1 to 4, wherein each process component has a temperature sensor.

6. The system of claim 5, wherein each flow control

valve is operated to control the temperature of the process component.

7. The system of claim 6, wherein each flow control valve has a temperature controller.

8. The system of claim 7, further comprising a central process controller in electronic communication with the temperature controllers.

9. The system of claim 8, wherein the central process controller provides a setpoint to each temperature controller.

10. The system of any of claims 1 to 9, wherein the plurality of process components are coupled to a common chamber.

11. The system of any of claims 1 to 10, wherein the plurality of process components are coupled to different cluster tools.

12. The system of any of claims 1 to 11, wherein the heat exchanger cools a fluid to a temperature that is less than the lowest temperature required by the process components.

13. The system of any of claims 1 to 12, wherein the heat exchanger heats a fluid to a temperature that is greater than the highest temperature required by any of the process components.

14. A semiconductor fabrication system, comprising:

    a first source of a heat transfer fluid;
    a plurality of fluid passages in parallel, fluid communication with the first source, each fluid passage having a flow control valve; and
    a plurality of process components, each process component in thermal communication with one of the fluid passages.

15. The system of claim 14, wherein the heat transfer fluid is supplied at a temperature that is less than the lowest temperature required by the process components.

16. The system of claim 14, wherein the heat transfer fluid is supplied at a temperature that is greater than the highest temperature required by any of the process components.

17. The system of any of claims 14 to 16, further comprising:

    a second source of a heat transfer fluid;
    a plurality of fluid passages in parallel, fluid communication with the second source, each fluid passage having a flow control valve; and
    a plurality of process components, each process component in thermal communication with one of the fluid passages.

18. The system of claim 17, wherein the first and second sources are in fluid communication with the same plurality of fluid passages.

19. The system of claim 17, wherein the first and second sources are in fluid communication with a different plurality of fluid passages.

20. The system of any of claims 17 to 19, wherein the second source of a heat transfer fluid is supplied at lower temperature than the first source.

21. A method of controlling the temperature of multiple processing components, comprising the steps of:

    providing a heat transfer fluid to a manifold; and
    flow controlling the heat transfer fluid to the individual processing components.

22. The method of claim 21, further comprising the step of maintaining a continuous flow of the heat transfer fluid through the manifold.

23. The method of claim 22, further comprising the step of controlling the pressure in the manifold.

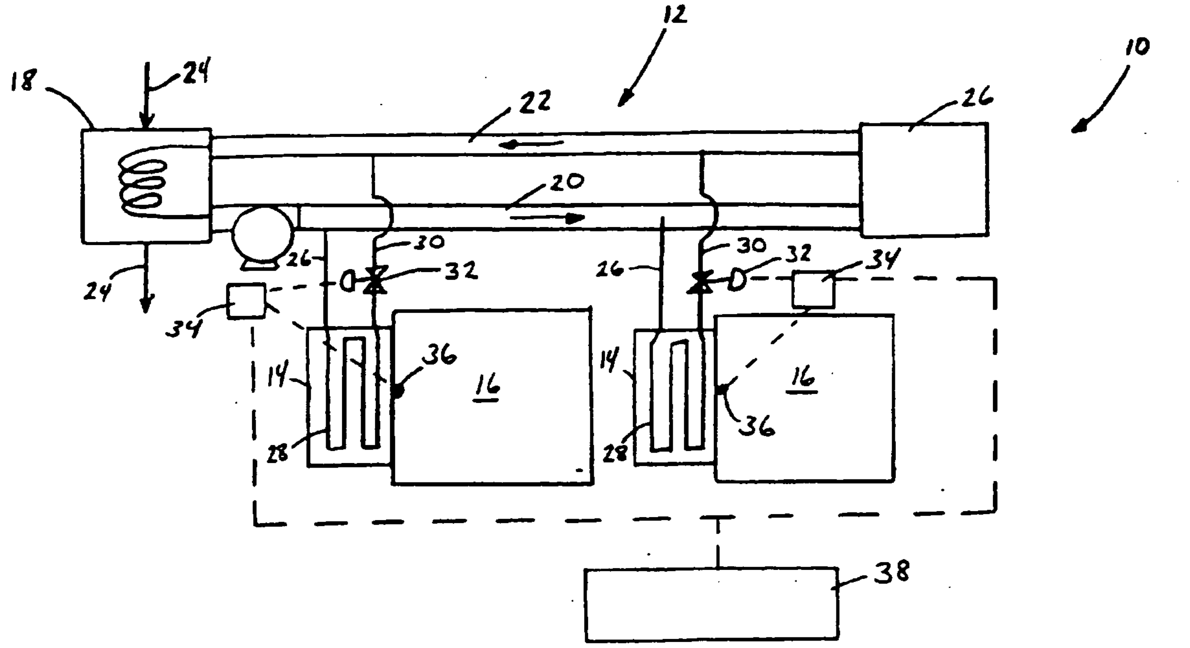
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FIG. 1

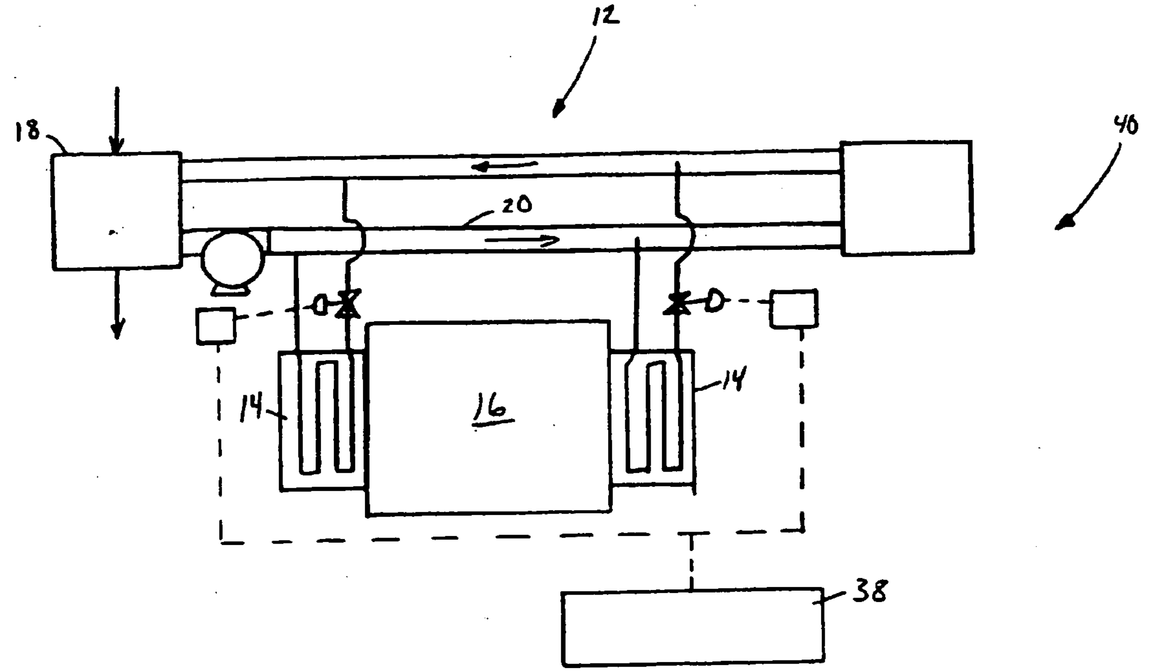
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FIG. 2

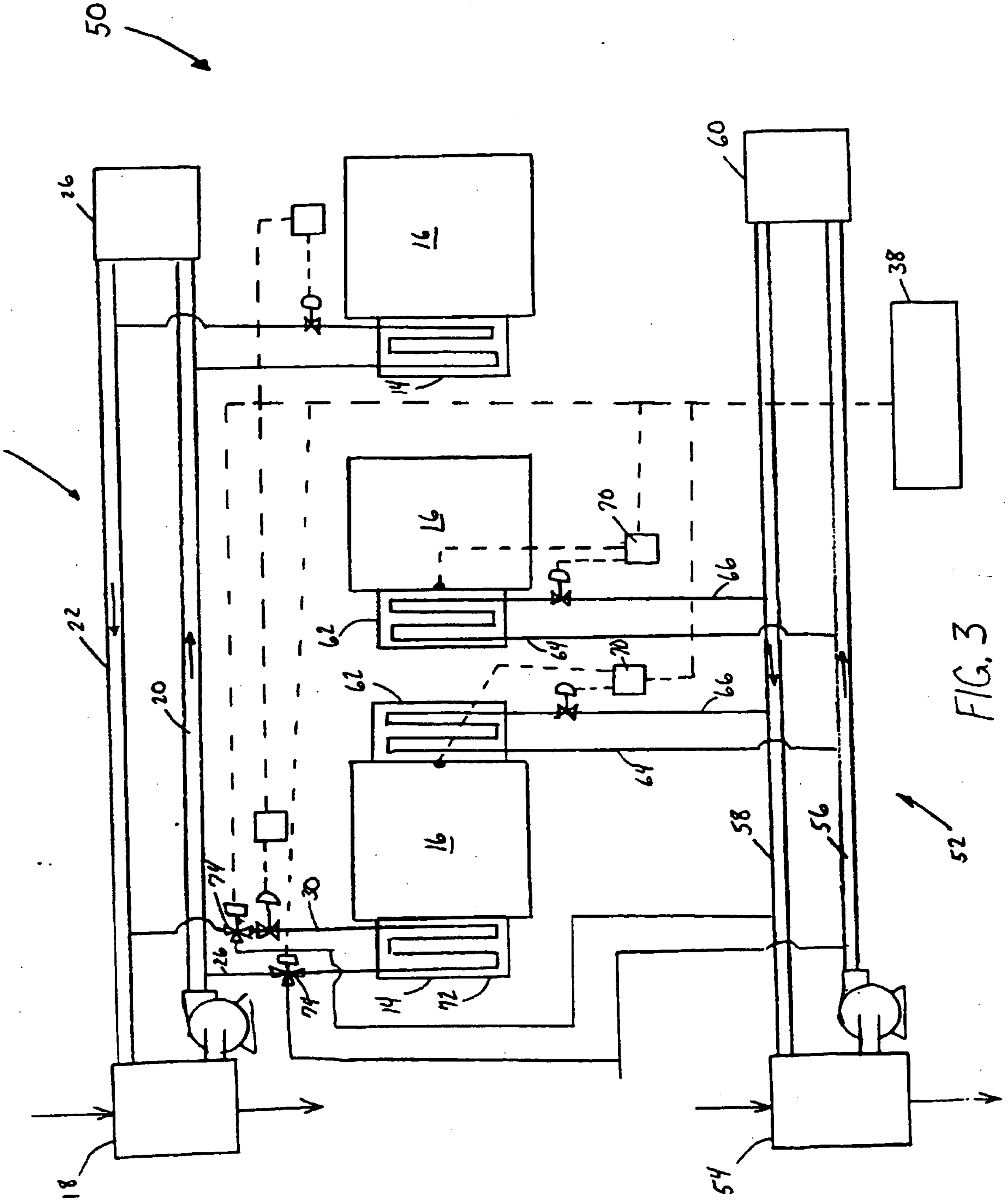
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FIG. 3

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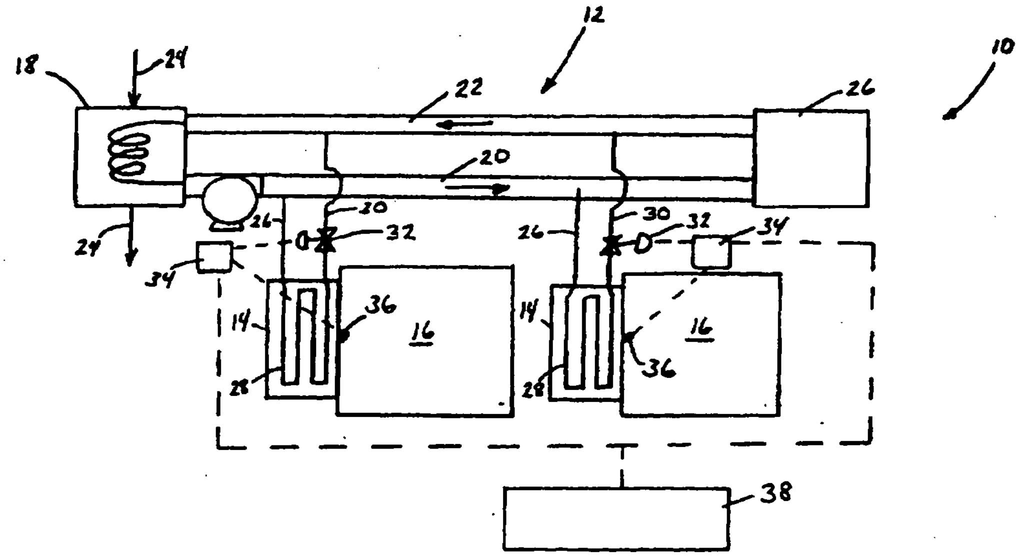

FIG. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 2285

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP 0 664 501 A (FSI INT INC) 26 July 1995 (1995-07-26)	1,2,4-6, 12,14, 15,21	H01L21/00
A	* column 2, line 46 - column 3, line 10 * * column 5, line 29 - line 40 * * claims 6,14,15 * ---	7-11,13, 16	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27 August 2001	Giordani, S

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EP 98 30 2285

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